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UNIVERSITY OF CINCINNATI

Bulletin No. X

SERIES II. Publications of the University of Cincinnati, VOL. II.

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The

Crayfish of Missouri

By

Mary Steele.

The University Bulletins are Issued Quarterly

Entered at the Post Office at Cincinnati, Ohio, as second-class matter

UNIVERSITY PRESS
Cincinnati, Ohio
1902

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Publications of the University of Cincinnati,

SERIES II. Edited by HOWARD AYERS. VOL. II.

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UNIVERSITY PRESS
CINCINNATI, O.

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INTRODUCTION.

The variations found within a species has been a subject of interest among scientists from the earliest history of biological sciences down to the present time. What it takes to constitute a species and at what point differences are important enough and constant enough to separate individuals into different species are still disputed questions.

In my taxonomic studies upon the crayfish of Missouri, Dr. Ayers called attention to the fact that the species of Cambarus within this state presented favorable material for the study of variations and further that the field was the more attractive because so little work of this kind had been done in the Mississippi River basin.

I have had an opportunity to examine a large number of individuals belonging to several species and have made a special study of the variations which a species presents. This has led me to conclude that, to say the least, it is very injudicious to name a species without having examined an abundance of material.

There is too great a tendency to overlook variations within a species and to multiply constantly the number of species much to the confusion of our system of taxonomy. This consideration, together with the fact that little or no work has been done upon the fauna west of the Mississippi by those acquainted with the territory has led me to present this paper for publication. Practically all of the taxonomic work that has been done in this part of the United States has been done by men from the East who have made flying trips through the country and collected whatever specimens came in their way. Generally they have not visited the territory but have merely classified material sent them by collectors.

Usually the material sent them has been very meagre and the descriptions of habits and habitats has been very inadequate.

In addition to the work already mentioned, I have also made a long series of observations upon the first and second forms of the males as found in *C. virilis*, the results of which are included in this paper.

During the observations many interesting points were suggested, for which I have as yet been unable to furnish any explanation; but which I hope to be able to further investigate some time in the future.

I desire to express my indebtedness to Dr. Howard Ayers, for suggesting the general plan of the work and for constant advice and assistance. I am also under obligations to Dr. Chas. Thom, for material. To Dr. Geo. Lefevre I am indebted for a careful examination of the MS.

THE CRAYFISH OF MISSOURI.

When Dr. Faxon ('85) published his "Revision of The Astacidæ, Part I. The Genera Cambarus and Astacus;" there had been reported from Missouri only seven species of crayfish, all belonging to the genus Cambarus; *C. blandingii.* Group I; *C. diogenes*, Group III; *C. medius*, *C. rusticus*, *C. immunis*, *C. harrisonii* and *C. virilis* Group IV. *C. bartonii*, of Group III, was also included as probably occuring.

These groups are the subdivisions of the genus Cambarus, according to Faxon, who has divided the genus into five different groups, basing his division upon the number of hooked thoracic legs and the shape of the first pair of abdominal appendages of the male.

The different species within the groups are distinguished by minor and less constant differences than those which determine the group. Differences in the shape of rostrum, breadth of areola, shape and size of chela, whether spines are few or numerous on carapace and claws, and the general contour of body are some of the features that are takeninto consideration in determining to what species an individual crayfish belongs.

Since Faxon's paper was published several other species have been identified as native to Missouri. Among these may be mentioned, *C. hayi*, Group I; *C. gracilis*, Group II; *C. setosus*, Group III, and *C. ayersii*, Group III. The last two are blind species. *C. ayersii* is now described for the first time, and *C. setosus*, was classified and named by Faxon ('89) and has as yet been reported from no other state.

Faxon has divided the territory occupied by the different species of Cambarus into two provinces, a southern and a northern one. The southern province embraces the Atlantic States south of North Carolina, the Gulf States and Cuba, and is characterized by the prevalence of species belonging to Groups I and II. The northern province includes the Atlantic States north of South Carolina, the Mississippi Valley States north of the Gulf States and Canada. In this province, forms of Group III and IV are dominant. However, species of Groups I and II are found in this province, and likewise species of Groups III and IV are found in the southern province. In fact there are five species from Group III, *C. acuminatus*, *C. latimus*, *C. extranus*, *C. girardianus* and *C. jordani*, and also three species from Group IV, *C. alabamensis*, *C. compressus* and *C. spinosus* that Faxon considers as restricted to the southern province. Only two species of Group I, *C. blandingii* and *C. pellucidus* and two species of Group II, *C. simulans* and *C. gracilis* had been reported from the northern province when Faxon published his paper. However, within the last three or four years there has been collected within this state another member of Group I, *C. hayi* and also a member of Group II, *C. gracilis*.

Heretofore *C. hayi* had been reported from but one state, Mississippi. Doutless other species seemingly restricted to the southern province would also be found in the northern if the territory were carefully searched; but the species which are found in Missouri centainly bear witness to Faxon's statement that Groups III and IV dominate in the northern province; for of twelve species that have been identified as certainly native of Missouri six species belong to Group IV and three to Group III, leaving but three species as members of Groups I and II.

GROUP I.

Beginning with the members of Group I, I shall give a somewhat detailed account of the species of Cambarus found in Missouri, without going into a systematic description of any except new species. So far only two members of Group I have been found in the state; *C. blandingii var. acuta* and *C. hayi.*

CAMBARUS BLANDINGII VAR. ACUTA, *Faxon.*

Under the head of *C. blandingii* (Harlan) Faxon (loc. cit. p. 19) has included a number of species decribed by other authors as synonyms of this species. Faxon also forms a variety (*C. blandingii var. acuta*) under this species and includes under the variety a number of species and varieties of other authors (loc. cit. p. 20.) This variety of *C. blandingii* occurs in Missouri but has been reported from but one locality, St. Louis. As to whether this species as found in Missouri shows any peculiarities I cannot say for the only specimens in the collection here came from Indiana.

Faxon says that the individuals of this species which are collected in the Western States differ considerably from those collected in the Southern States, and he considers the differences of the Western species from the Southern, characteristic enough to form of the Western species a sub-variety under *C. blandingii var. acuta.*

CAMBARUS HAYI, *Faxon.*

C. hayi, as was mentioned above had only been reported from Mississippi until April 10, 1897 when this species was taken from James River, Mo. *C. hayi* is very clocely related to *C. blandingii* but is easily distinguished from it by the first pair of abdominal appendages of the male, the deeply excavated rostrum and the shorter antennal scales.

Since *C. hayi* is not known except from two states and only a few individuals have ever been taken, it would appear that the species is not at all prolific. However, individuals attain a very considerable size. The following are the measurements of a first form, male. Length from tip of rostrum to tip of telson 113 mm.; length of carapace 56 mm.; width of carapace 33 mm.; length of hand 67 mm.; length of movable finger 36 mm.

GROUP II.

CAMBARUS GRACILIS, *Bundy*.

Plate III—Fig A_1, to A_5 and B_1 to B_8.

Only one species of Group II, *C. gracilis*, has been reported from Missouri, and all specimens found belong to the collection here. Most of them were found in the vicinity of Columbia, although specimens have been taken near Mexico, Audrain County.

C, gracilis, is one of the burrowing species and is seldom found except during February and March. Then the females come from their burrows along the banks of creeks and ponds, out into the water with their newly hatched young. By the latter part of March the adults have returned to their burrows. The young however may still be found in the open water during April and May.

Faxon mentioned that among the hundreds collected along the water-courses in the spring time, but few males have been found. The same is true of the collection here. From sixty-two adult specimens collected March 10, 1897, only two are males, the larger of these being but 69 mm. in length. Among the adult specimens taken in this vicinity March 1899 not a single male was found. The collection taken last spring, March 1900, contained no males.

However, this does not hold true for small specimens, for out of fifty-two of the young, 25–35 mm. long, taken at the same time and place as the sixty-two adult specimens, twenty-seven were males and twenty-five were females. Also among the young individuals collected in March 1899, I find as many males as females. The same is also true of the collection for 1900. This shows that while they are young, males are as plentiful as females and come from the burrows in as great numbers.

Although *C. gracilis* is seldom found except in early spring, I once found a solitary adult female in July, crawling across a clayey road just after a heavy rain. A solitary adult male about 50 mm. in length was found at Columbia, under a log in June 1897. Last summer August 1899, I captured two males in their burrows. The burrows were out on the open prairie some distance from any stream. Those that I investigated were along a new road that was being graded. One of the workmen who happened to know of my interest in crayfish noticed the burrows and told me of them. He also said that the crayfish worked at night, for during the day the burrows were plowed over and their openings stopped, but in the morning when he came out to work the same holes were again opened up and surrounded by a small heap of fresh earth. I determined to visit the burrows myself. Accordingly, accompanied by my father and the workman who had told me of them, I visited the burrows between eight and nine o'clock P. M., although many of the burrows were found, in none of them did I find a crayfish at work. It was decided to dig some of the burrows out. The burrows descended vertically into the ground for about four feet; the main tunnel varying from an inch to an inch and a half in diameter. The tunnel was terminated by a flask-shaped enlargement, the greatest diameter of which was about six inches. This enlargement was partially filled with mud and water.

Several burrows were dug out, but only two contained crayfish, one in each. From one we took a male, and from the other a female, each about 55 mm. in length. If the crayfish came out at night, we must have been too early for them, and since the earth which the workman found around the mouth of the burrow in the morning was still moist, it seems probable that they do their work towards morning.

C. gracilis has much the general form of *C. diogenes* of the same region, except that it is smaller. The male appendages differ considerably from those of *C. diogenes*; also the annulus ventralis is quite different in the females of the two species. In *C. gracilis* the annulus is movable and is denticulate on the anterior border, while in *C. diogenes* the annulus ventralis is bounded anteriorly by two blunt tubercles. Besides, the female *C. gracilis* lacks the battered appearance that is characteristic of the old specimens of the female *C. diogenes*. These differences easily distinguish the females of the two species which are often found in company.

C. gracilis does not attain as great a size as many other species of Cambarus. The largest *C. gracilis* I have ever seen does not exceed 82 mm, while it is not at all unusual to see *C. virilis* and *S. diogenes* 120 mm. long.

The females differ from the males in having a shorter hand and broader abdomen. A male of 69 mm. has a hand 30 mm. long and 12 wide, while a female of 82 mm. has a hand only 27 mm. long and 11 mm. wide.

Very little variation is to be noticed among adult individuals of *C. gracilis*. This may be due in part to the scarcity of the male specimens for in all species the males show much greater variation than the females. The fact that this is a burrowing species and consequently less subject to varying conditions than crayfish that do not burrow may to some extent explain their uniformity of parts. Even in collections of immature forms where males are numerous there is found much less variation than among individuals of the same age belonging to other species. *C. virilis* for instance, a species which shows much individual variation.

As is well known, the young Cambarus of any species differs much in some of its parts from the adult forms. I have had no opportunity to examine *C. gracilis* less than 7 mm. in length; but individuals 7 or 8 mm. long show varations in breadth of areola and length and shape of rostrum. At this age the rostrum is still short and bent down between the eyes, as in the case with all newly hatched crayfish. However, in adult *C. gracilis* the rostrum is short as compared with most species of Cambarus, and is bent downward between the eyes so that it fits closely over the antennules. I attribute this form of rostrum to the burrowing habits of the species.

Specimens of *C. gracilis* 28–35 mm. long are but little different from mature forms, so far as general appearance goes, but careful observation shows an important variation from the adults in both males and females. The annulus ventralis is not denticulate on the anterior border, nor does it have the characteristic appearance from behind of two interlocked crescents; it is also much less grooved and convoluted than in the adult female. In the adult males of this size, 30–35 mm., the first pair of abdominal appendages are slender and unarmed much as one would expect to find second-form adult males; but Faxon says he has never seen a second-form male *C. gracilis*, and from what I can learn none have ever been reported. The antennal scale in the young individuals is relatively broader and is truncate at the apex, and also has the apical spine much shorter than in the adult. Upon measurement there is found to be some variations in relative lengths of cephalothorax and abdomen, although not nearly so much as *C. virilis* shows.

Below are measurements in mm., of twelve individuals; the first column giving length of the body, the second, length of abdomen, and the third length of cepalothorax.

BODY.	ABDOMEN.	CEPHALOTHORAX.
32.5 mm.	16.5 mm.	15.0 mm.
37.0 “	19.0 “	18.0 “
30.0 “	15.0 “	15.0 “
31.0 “	16.0 “	15.0 “
35.0 “	17.5 “	17.0 “
30.0 “	15.0 “	15.0 “
32.0 “	15.5 “	16.5 “
28.5 “	15.0 “	13.5 “
28.0 “	14.0 “	14.0 “
31.0 “	16.0 “	15.0 “
33.5 “	16.5 “	17.0 “
32.0 “	15.5 “	16.5 “

In noticing these varations it will be seen that the length of the cephalothorax and abdomen is equal in some cases, but that in the majority of cases the abdomen is longer than the cephalothorax. Now there is also a variation in these relative lengths in adult specimens, but instead of the abdomen in most cases being equal to or greater in length than the cephalothorax the reverse is the case, as may be seen in the appended columns of measurements of the mature gracilis.

BODY.	ABDOMEN.	CEPHALOTHORAX.
70.0 mm.	35.0 mm.	35.0 mm.
54.0 "	25.0 "	29.0 "
55.0 "	29.0 "	26.0 "
79.0 "	39.0 "	40.0 "
57.5 "	29.0 "	29.5 "
50.5 "	24.5 "	25.5 "
61.0 "	29.5 "	30.5 "
57.5 "	29.0 "	28.5 "
77.0 "	37.0 "	40.0 "
69.0 "	34.0 "	35.0 "

Faxon (loc. cit. p. 57) describes *g. gracilis* as having the abdomen shorter than the cephalothorax by the length of the rostrum, but this cannot be said of the specimens which I have at my command. Although a majority of those measured show an abdomen shorter than the cephalothorax, in most cases the cephalothorax does not exceed the abdomen more than from 0.5 to 1.5 mm., which is not so much as half the length of the rostrum of a mature *C. gracilis*.

I have not yet been able to decide fully at what age and size *C. gracilis* becomes mature. But since the first pair of abdominal appendages of the male and the annulus ventralis of the female both have characteristic forms in the adults which are quite different from the form of these organs in the immature individuals, it occured to me that a graded series of these appendages might be useful in determining the maturity of individuals. It may also serve as a guard against mistakes in classification, for if only immature forms of a species are at hand one may class them as mature individuals of a different species.

Plate III,—Figs.—A_1 to A_5 show a graded series of the first pair of abdominal appendages of the male. Fig. A_1 is taken from a crayfish only 23 mm. long. These appendages show very little modification from the typical abdominal appendage. Figs. A_2 and A_3 show an increased modification, and by the time the crayfish is 40 mm. in length the appendages have become modified as in Fig A_4. The crayfish may be adult at this stage. I have found females very little larger, that were in berry. Fig. A_5 shows the appedages from a male 67 mm. long. So far as I have been able to observe, this figure represents the typical appearance of this pair of appendages in the large male *C. gracilis.*

Plate III, B_1 to B_8 show the modifications through which the annulus ventrails passes during the growth of the female *C. gracilis.* Fig. B_1 drawn from a specimen 20 mm. long, is very simply formed, and the central depression is very slight. The complexity of structure and increase in depth of central depression gradualy increases with the age and size of the animal, until the annulus ventralis of the larger females (Figs. B_7 and B_8) presents a very complicated and characteristic structure. Figs. B_1., as stated above, is taken from a specimen 20 mm. in length; Fig. B_2 from one 22 mm.; Fig. B_3, 27.5 mm.; Fig B_4, 30 mm; Fig. B_5, 35 mm.; Fig. B_6, 36mm.; Fig. B_7, 50 mm.; and Fig. B_8 60 mm.

I think that Figs. B_7 and B_8 can both properly be regarded as belonging to adult individuals, for I have found females of *C. gracilis* not exceeding 40 mm. that were in berry.

However, Fig. B_8 can be considered the more typical form of the adult annulus ventralis of the female *C. gracilis.*

One other point should perhaps be mentioned before leaving the consideration of this species. That is concerning their moulting season, which so far I have been unable to determine.

As is well known young crayfish of any species have no particular, well-defined moulting season, but may moult at almost any time during the year. This is no less true of *C. gracilis* than of other species. However, of the adult forms I have been entirely unable to find one moulting at any period whatever.

It is impossible that the moult should have taken place before the spring collections were made, for often the females that were captured had the newly hatched young still clinging to the swimmerets. Besides, amoung those that carried no young there was no sign of a recent moult.

I have kept them through the summer and far into the following winter without a molt occuring. The specimens mentioned above which were taken from their burrows in

August, were kept through the fall, winter and the following spring, when they died without having moulted.

C. gracilis has been under observation at all seasons of the year, but I have not seen one over 30 mm. in length pass through a moult. Laboratory conditions might retard their moulting, but it is improbable that these conditions should prevent moulting. *C. gracilis* thrives under laboratory treatment, and is hardier and more easily kept alive than some other species.

In experimental work on the appendages of crayfish I found the young of *C. gracilis* to grow more rapidly and withstand mutilation as well if not better than the young of *C. virilis*.

GROUP III.

CAMBARUS BARTONII, GIRARD.

For synonymy see Faxon (loc. cit. pp. 59, 60.)

Faxon (loc. cit. p. 61) mentioned *C. bartonii* as probably belonging to Missouri, but, although several new species have been discovered in the state since that date, this species has not been found.

C. bartonii is taken as a type of Group III. It has a wide geographical distribution, and, as might be expected, is subject to much variation. These variations affect especially the rostrum, chelæ, areola, antennal scales and epistoma. In the common Eastern form the rostrum is short, broad, and almost plane above, the sides nearly parallel from the base almost to the tip, where they suddenly converge to form the short acumen. The chelæ are coarsely punctate, the inner margin of the hand sub-tuberculate, and the fingers gaping at the base. The areola is quite narrow, and the antennal scale is narrow.

The Western specimens have a longer, narrower rostrum, the margins of which converge gradually to form a longer acumen. The areola is wider, and the antennal scale broader at the base. The chelæ are smoother and in some individuals bearded at the base.

Although the extreme Western forms differ much from the extreme Eastern, there are so many intermediate gradations between them that Faxon does not consider it justifiable to classify these extremes as different species.

C. bartonii is the only eyed species that is known to inhabit Mammoth Cave. It is found there in company with a blind species, *C. pellucidus*, a member of Group I. Some writers have been led to conclude, by finding *C. bartonii* in company with the blind species, that *C. pellucidus* has been directly derived from *C. bartonii*, but Faxon, after a careful comparison of likenesses and differences of the species, and in consideration of the fact that the general characteristics of *C. pellucidus* (Tellk.) place it in Group I., suggests that it is probable that the origin of the blind species dates much farther back than would be possible were it derived from *C. bartonii*. He says (loc. cit. p. 42): "The simple form of the male appendages and the combination of characteristics belonging to different groups seen in *C. pellucidus* indicate to my mind that it is a very ancient form, which has been preserved in the seclusion of the cave while its nearest kin succumbed to the sharper struggle incident to life outside, or were replaced by modified descendants evolved to meet the changeable conditions which obtain without the caverns. This view is rendered more probable when one remembers that this same blind form *C. pellucidus* occurs in the Wyandotte Cave on the other side of that ancient river, the Ohio.' The transportation of an eyeless species from the Kentucky caverns to those of Indiana seems out of the question, and one is driven to the conclusion that the subterranean waters of both localities derived this eyeless species from a simpler form with well-developed eyes, that peopled the streams throughout this region at a remote period."

CAMBARUS SETOSUS, FAXON.

Although *C. bartonii* and *C. pellucidus* can not be regarded as closely allied species, there are two blind species of the Bartonii Group for which a close relationship can be claimed. These are *C. hamulatus* and *C. setosus*. The latter has been reported from Jasper County, Missouri, but from no other locality. It was first named and described by Faxon ('89). Miss Ruth Hoppin collected this species from Wilson's Cave and wells in the central part of Jasper County. Samuel Garman ('89) quotes from letters of Miss Hoppin a description of the wells and cave. I reproduce a part of the description here:

"The cave is about fifty feet long and nearly as wide, oven-shaped and high enough to stand in, except around the sides. * * * A small, very clean stream flowed along the left side, having a width of two feet and a depth of three, with temperature of plus 54° F. About ten feet from the entrance the light struck the stream in such a manner that we could see everything in the water without a lantern. The first things that caught the eye were a lot of crayfish, a dozen in all, like those I took from the wells. It seemed as if I might take every one of them. But though blind they have one or more of the other senses very keenly developed. I am very sure that they, as well as the white fishes, have the tactile sense developed to an unusual degree. At the least touch upon the water they dart away. * * * The crayfish were all found near the entrance, where there is considerable light. * * * I concluded that the crayfish liked the light. Perhaps they remain near the entrance because there they find a supply of food. From one well thirteen blind crayfish were taken, from another two, and from another one. * * * One well, an artesian, went dry when a neighbor dug another farther down the hill. It was found that the first well opened at the side directly into a small cave. All these are in limestone; only in this formation is good water to be obtained hereabout. The larger caves in this vicinity are under the limestone cliffs and hills that skirt Centre Creek. The wells are usually walled with stones that leave spaces through which the fishes may pass. There are probably many small subterranean springs and streams, not one underlying lake, as popular belief has it."

Garman (loc. cit. p. 231) says of these caves that "It is evident from the notes that these caves are numerous and similar to those in the same formation in other states."

Besides the crayfish, several other species of animals were found in the caves and wells, and Garman feels sure that further collecting will reveal several other interesting forms. Of the Crustacea he says (p. 235): "In part, at least, the problem of the origin of the cave crustacea is simplified by the fact that they are so distinct in various caves as to leave no doubt that they are descended from ancestors already of different species at the time of entering subterranean habitations. The blind crayfish of the Missouri caves is very distinct from any previously known; it is described under the name *Cambarus setosus*. The common species of the neighborhood, *C. virilis*, is also found to enter the underground retreats, but it is not of the outside forms, the nearest ally of the blind form. The latter bears so close an affinity to *C. bartonii* as to suggest derivation from it. A somewhat parallel condition exists in the caves of Missouri and those of Kentucky. In these last, with the blind

C. pellucidus we find *C. bartonii*, the nearest ally of the blind crayfish in Missouri, *C. setosus*, and with the latter again in the Missouri caves is found an eyed species, *C. virilis*, more nearly allied to the blind one in the Mammoth Cave. The relationship existing between the species *C. setosus* and *C. bartonii* is much closer than between *C. pellucidus* and *C. virilis*. A distribution of *C. bartonii* covering so large a portion of the Upper Mississippi Valley to some extent favors the idea of the derivation from it of *C. setosus*. The greater difference between *C. pellucidus* and all known eyed species points towards a longer subjection of that form to the spelæan influences."

C. hamulatus (Cope, Faxon), the blind species from Nickajack Cave, Tennessee, stands between *C. setosus* and *C. pellucidus*, but nearer to *C. setosus*. *C. hamulatus*, however, does not occur in Missouri.

CAMBARUS AYERSII, N. SP.

Plate V., Fig. A.

In 1897 Dr. Howard Ayers found in the stream in Fisher's Cave, near Springfield, Missouri, a species of blind crayfish which belongs to the *C. bartonii* group, and in some respects resembles *C. setosus* very closely, yet it differs much in others. On account of these differences it is here described as a new species.

Male, form II. — Rostrum medium length, shorter than the antennal scales, slightly concave above, with short acute lateral spines; acumen triangular, acute. Postorbital ridges short, terminated by an acute spine. Carapace subcylindrical, flattened and smooth above; portion of carapace behind cervical groove very long; sides of carapace behind cervical groove coarsely granulate, in front of cervical groove finely spinulate; branchiostegian spine short, acute, antennæ slender and longer than the body. Hand long and slender, inner border ornamented with a row of small, sharp tubercles. Carpus slender, with deep indentation on dorsal surface, inner margin with four sharp spines, lower surface with two sharp spines. Upper margin of the meros subdentate, lower surface of meros furnished with sharp spinules arranged bi-serially. Upper surface of the basal segments of the antennules ornamented by tufts of rather long setæ. Third pair of legs hooked. First pair of abdominal appendages fashioned after the type of *C. bartonii* Group; short, articulated at the base, dilated in the middle;

tips bifid, ending in two short recurved corneous hooks which are closely approximated, the outer hook being visible from the median aspect, tip of the inner hook slightly attenuated. A few fine setæ are scattered on the dorsal aspect of the abdomen.

Measurements of Male, form II. — Length from tip of rostrum to posterior border of telson, 66 mm.; length of cephalothorax, 32 mm.; length of abdomen, 34 mm.; length of rostrum, 45 mm.; length of antennæ from base of antennal scale to tip, 89 mm.; length of hand, 32 mm.; breadth of hand, 9 mm.

The chief differences between this species and *C. setosus* lie in the presence of postorbital ridges, postorbital spines and rostral spines, which are well developed in these specimens, while they are described as absent in *C. setosus;* also in the breadth of areola. *C. setosus* is described as having a narrow areola, while in this species it is strictly linear. Then again, the first pair of abdominal appendages are not like those described for *C. setosus*. Garman (loc. cit. Pl. I.) figures and describes the first pair of abdominal appendages of the male *C. setosus*, and, although he figures three different forms that these appendages may take, none of them correspond to the form of appendage found on the species *C. ayersii*.

From the figures and description of Garman it is certain that this species is not *C. setosus*.

Since writing the above I have received from Dr. C. Thom a small (31 mm. in length) living specimen of blind crayfish which was taken from a well sixty feet in depth at Joplin, Missouri. It is not unusual to find these blind crayfish in that vicinity.

It had been kept a week or two before I was able to make observations on its behavior in confinement. I can get no evidence that the rudimentary eyes are sensitive to light or are more sensitive to touch than other parts of the body. When placed in a glass jar with paper on one side it hides on the shady side. This crayfish lived but a short time, and was not active in captivity. It was almost colorless, and the carapace was translucent. Wilson's Cave, where *C. setosus* is found, is not more than fifteen or twenty miles from Joplin.

In many respects this specimen accords with the description of *C. setosus*. In others it differs from *C. setosus*, yet not more than could be accounted for by its small size and the fact that it is a female. As is well known, even among eyed crayfish the females alone are not sufficient to satisfactorily determine a species.

C. setosus is described as having antennæ as long or longer than the body. In this specimen they are considerably shorter. The chelæ have very much the general shape described for *C. setosus*, but are scarcely spiny at all, and are less setose. Again, the areola could not well be described as narrow, for it is of medium width; but this may be due to its being a young specimen, for the areola in immature crayfish is proportionately broader than in adults.

Miss Hoppin states that among living specimens the young *C. setosus* are not so white as the older ones, and she also says that the specimens became opaque when placed in alcohol, although in life they are so transparent that the movements of the internal organs can be seen. In this specimen, which has now been in alcohol five months, I can not see that its color or transparency has been materially altered from what it was in life. The part of the carapace in front of the cervical groove is still so transparent that, with a magnification of ten diameters, the fibers of the gastric muscles and the cœca of the hepatic gland can readily be seen.

This specimen differs still more from *C. ayersii* than from *C. setosus*. The general contour of the body resembles that of *C. ayersii*, but the relative lengths of the abdomen and cephalothorax differ more, the abdomen being 3 mm. longer than cephalothorax, while in *C. ayersii* it is only 2 mm. longer. Again, in *C. ayersii* the antennæ are much longer than the body, while in this specimen they are not so long. The hand is not spiny, and only very sparsely setose. The carpus is without the conspicuous indentation on its dorsal surface found in *C. ayersii*, and has but one spine on the lower surface and one on the inner border. The lower border of the meros has a double row of very fine spinules. The rostrum is more concave than in *C. ayersii*, and the rudimentary eyes less completely hidden underneath it. The antennal scales are longer than the rostrum.

Altogether, I consider that this small specimen shows more points in favor of *C. setosus* than in favor of *C. ayersii*.

CAMBARUS DIOGENES, GIRARD.

For synonymy see Faxon ('89, p. 71).

This species has a widespread distribution over the United States. It extends north to the Great Lakes, south to the Gulf, east to the Atlantic coast and west to the Rocky Mountains. In Missouri it has been found in Carroll, Boone and St. Louis Counties. In the general form of its body and in its habits it resembles *C. gracilis,* and is often collected in company with this species. In one collection are five crayfish taken at the same time from Rollin's Pond, near Columbia. Of these five specimens, two are large first-form males of *C. diogenes;* the other three are medium-sized females of *C. gracilis.* Unlike the males of *C. gracilis,* the males of *C. diogenes* are found in as great abundance as the females.

In discussing *C. gracilis* I have mentioned the resemblances between these two species. Specimens of *C. diogenes* from the same locality vary much. In some the rostrum is deeply excavated. The rostrum of the females is bent down at a greater angle than the rostrum of the males. In the females the abdomen is noticeably broader and flatter than in the males. This is true to some extent of all species, but it is more pronounced in *C. diogenes* than in any species I have studied.

Faxon says the Western specimens are larger than the Eastern ones. He also notes other differences between the Eastern and Western specimens. In individuals from the East the areola is not completely linear, the rostrum is narrower, and the epistoma narrower than in individuals from the West. He considers these specimens sufficiently different from the Western form to be classed as a variety, and he calls them *C. diogenes, ludoviciana.*

C. diogenes is pre-eminently a burrowing species. It is often found at a great distance from surface water, as in stream, in meadows and cornfields.

Several accounts of their burrows and mud chimneys have been written. Audubon ('44) is the first to figure and describe the mud chimneys built by *C. diogenes.* His description of them is in connection with his description of the ingenious manner in which the White Ibis draws the crayfish from its hiding place.

Girard ('52) has also given an account of their burrows and chimneys. His observations were made in the vicinity of Washington, D. C. A part of his description I quote here: "The holes as they appear at the surface of the ground are nearly circular, and vary from seven-tenths of an inch to an inch and a half in diameter. The depth of the burrows varies with the location; these we generally found to be from sixteen inches to two feet, and sometimes to three feet and more. * * * From the surface of the ground the excavation exhibits a gradual slope, in direction more or less undulating, for a distance from five to ten inches, when it becomes vertical for six or eight inches, and then terminates in a sudden bottle-shaped enlargement, in which the animal is found. The bottom of the burrow having no subterranean communication, no other issue except towards the surface, it is entirely isolated from its neighbors and leaves no chance for escape to its inhabitants. The same burrow may have several external holes connected with it, several inclined channels, which, however, meet at the depth where it becomes vertical. We found constantly the cavity full of water, but this was in March and April. The bottom for several inches was filled with soft, pulpy mud.

" There are other instances of burrows somewhat more complex. Their direction may be oblique throughout their whole extent, and composed of a series of chambers or ovoid enlargements succeeding each other at short intervals. Sometimes, also, and connected with one of the chambers, a narrow and nearly tubuliform channel extends downward to a much greater depth, and appears to us as a retreat either during the cold winter or else during the dryness of summer, when the water is low. That it is not for the mere purpose of escaping pursuit we infer from the fact that we repeatedly caught the animals in the chambers above, where they remained quietly instead of attempting to disappear into the compartments below.

* * * * * * * *

" In the spring, and, we are told, in the fall also, the burrowing crayfish builds over the holes of its burrow a chimney of the maximum height of one foot, but most generally lower. The chimney, circular-pyramidal in shape, is constructed of lumps of mud varying in size, irregularly rolled up and piled up, one upon each other, and intimately cemented together. Its exterior has a rough and irregular appearance, whilst the interior is smooth and as uniform as the subterranean channel having the same diameter."

Girard stated that the crayfish worked at night, but that he had never been able to see the animal at work. However, since that time Dr. Abbot ('95) has published a paper in which he states that his nephew, Mr. Joseph De B. Abbot, has seen the crayfish engaged in building its chimney. The observation was made at night by the light of a candle. The crayfish was seen to emerge partially from its burrow, bearing " on the back of its right claw a ball of clay mud which, by a dextrous tilt of the claw, was placed on the rim of the chimney. Then the crayfish remained perfectly quiet for a few seconds, when it suddenly doubled up and dropped to the bottom of the burrow. There elapsed some three or four minutes between each appearance, but every time it came it brought a ball of clay and deposited it in the manner I have described. About two-fifths of the balls were not placed with sufficient care, and rolled down the outside of the chimney."

Besides the descriptions of the habits of these burrowing crayfish which I have already quoted, I may also mention papers by R. S. Tarr ('84) and Dr. C. C. Abbot ('84).

Tarr believes that the chimneys are merely the result of the excavation of the burrows, a sort of accidental accompaniment, and imply no design on the part of the crayfish. On the other hand, Dr. Abbot believes them to be due to a definite and carefully executed purpose on the part of their architects. They are often built on the steep banks of ditches, where the ejected mud would surely roll into the ditch if not carefully arranged to prevent it. In several instances observed by Dr. Abbot, where the chimneys were built on sloping banks, the base of the chimney was provided for by leveling the ground before the foundation of pellets of mud was laid. From observations made on forty of these towers or chimneys, Dr. Abbot is convinced that not one of the forty could be the result of accident.

From the observations made up to this time, no one has been able to give a satisfactory explanation as to the object in building these elaborate burrows and the seemingly carefully erected towers. More knowledge concerning the winter habits of the animal, and its mode of life during the breeding season, would perhaps throw light upon the purpose of the towers and burrows.

C. diogenes is not plentiful in Central Missouri, and in this region the mud chimneys are built about eight inches high, and are formed of pellets of mud of regular size and shape. On the inside the chimneys are plastered smooth, and outside they have the characteristic rough appearance due to being formed of mud balls.

GROUP IV.

The remaining species of crayfish found in Missouri belong to Group IV.

A male of this group is easily distinguished from one of any other group by the form of the first pair of abdominal appendages, which are more slender than in any other, and in the first-form males they are always terminated by two slender and, in most species, nearly straight styliform tips.

Beginning with the species which is least plentiful in this state, I shall treat of the members of this group in the order of their abundance.

CAMBARUS HARRISONII, FAXON.

This species has been reported from but one locality in the state, Irondale. We have no specimens in the collection here. Faxon (loc. cit. p. 95) says that *C. harrisonii* resembles *C. rusticus* in general form, but that the first pair of abdominal appendages of the male and the annulus ventralis of the female differ conspicuously from any other species of the group. Faxon figures the first pair of abdominal appendages very short and thick; the rami short, rather blunt and slightly curved. These appendages would suggest a close relationship with Group III. *C. harrisonii* is probably a border species. No second-form males have been reported.

CAMBARUS WHITMANI, N. SP.

Plate V., Fig. B; Plate III., Figs. C1 and C2.

This crayfish was taken from the James River, Missouri, on August 20, 1897. It appeared at first to be a variation of *C. palmeri* (Faxon), but upon careful examination I find that it differs in important distinguishing characteristics. No other species has been described with which this species can be identified.

Male, form II. — Rostrum long, deeply excavated, margins nearly parallel from base to lateral spines, which are acute, short and corneous; acumen long. Postorbital ridge terminated by a blunt spine. Carapace punctate above and granulate on the sides; lateral spine large; portion behind cervical groove flattened on top. Areola very narrow, with a small anterior and large posterior triangular field. The length of the areola is one-half the distance from the cervical groove to the tip of the rostrum. Abdomen broad, as long as the cephalothorax. Proximal segment of the telson bispinous on each side, distal segment slightly concave on posterior border. Antennæ long; laminæ slightly longer than the rostrum, broadest in the middle, tapering to a short spine at the apex. Third maxillipeds hairy within. Anterior process of the epistoma notched at the apex. Chelæ long, smooth and punctate, margined on the outer edge. Hand straight, inner margin straight and short, with a double row of small ciliated tubercles. Fingers long and straight, with corneous incurved tips, punctate and ciliate above. Movable finger furnished with a double row of ciliated tubercles on basal half of the outer edge. Outer finger hairy below at the base. Opposable edges of the fingers bluntly tuberculate. Carpus with three spines on interior border; smooth below, with two prominent anterior spines. Meros with two spines on upper surface, outer row of inferior biserial spines reduced to two well-developed spines, large sharp spine on anterior border. Third pair of legs hooked. First pair of abdominal appendages articulated at the base, stout, long and straight, bifid for a short distance from the tip, rami divergent, outer one the longer.

Below are given the measurements of a large male, form II.: Length from tip of rostrum to tip of telson, 120 mm.; length of rostrum, 14 mm.; breadth of rostrum at the base, 5.5 mm.; length from tip of rostrum to cervical groove, 40 mm.; length of areola, 20 mm.; breadth, 1 mm.; outer margin of hand 68.5 mm., inner margin 15 mm.; movable finger, 49 mm.

This species is closely related to the recently described subspecies *C. palmeri longimanus* (Faxon); in some particulars it resembles it more than *C. palmeri*. But the shape of the hand and the first pair of abdominal appendages is so different that they can not belong to individuals of the same species.

Plate III., Figs C1 and C2 show the hand and first pair of abdominal appendages of the male of *C. whitmani*, whose measurements are given above. The hand is drawn natural size and the appendages one-half longer than natural size.

Plate VI., Fig. 2 is reproduced from a photograph of the same individual from which the hand and abdominal appendages are drawn.

CAMBARUS IMMUNIS, HAGEN.

Plate III., Figs. D1 to D3, E1 to E3.

For synonomy see Faxon ('89, p. 99).

Until recently this species had been reported from only one locality in the state, St. Louis. During the period covered by my studies it has been collected from a number of localities in the northern part of the state. We have in the collection here specimens from St. Louis; Mexico, Audrain County; Canton, Lewis County; Chillicothe, Livingston County; Martinston, Putnam County, and from St. Joseph.

This species inhabits ponds and creeks, and in rainy weather individuals are often found crawling freely about in the meadows and fields and along the roads.

In typical specimens *C. immunis* has a rostrum without latent teeth, but it is not unusual to find, especially in young individuals, small rostral spines.

Our collection of *C. immunis* contains seventy-five or eighty specimens, too small a number to base a study of variation upon. However, the following differences have been noted:

Plate III., Fig. D1 shows the chelæ, first pair of abdominal appendages and the rostrum of a first-form male 67 mm. in length. Hand with curved external border, movable finger with characteristic notch on the inner border; base of fingers densely setose. Two spines on internal border of carpus, one spine on upper surface of meros. Rostrum triangular and sharp-pointed. Abdominal appendages small, curved and with scattering setæ on the proximal half of the internal border.

Plate III., Fig. D2 shows chelæ, rostrum and first pair of abdominal appendages of a first-form male 73.5 mm. in length. This specimen is from the same locality as the specimen of Fig. D1. The hand is long, narrow and straight and without the notch at the base of the movable finger. The carpus has two spines on the inner border. Meros is destitute of spines on upper surface. The setæ are less developed, both on the chelæ and on the abdominal appendages, than on the specimen of Fig. D1. The rostrum is broader and more sharply pointed. This claw without a notch is, I think, a regenerated one. I infer this from the fact that in several instances I have found individuals upon which the claw on one side was without the notch, while the one on the other side had the notch. In every instance where this is the case the claw without the notch is the smaller of the two. I have also found specimens where both chelæ were devoid of the notch. On the same hypothesis I take it that in such cases both chelæ have been taken off, and that these straight claws are regenerated ones. This view is borne out by the fact that such claws are always undersized for the individual. I have not observed the regeneration of a chelæ in *C. immunis*, but in *C. virilis* the regenerated claw passes through at least two moults before it takes on the appearance of a normal claw. The notched or hooked appearance of the claw of *C. immunis* is mainly due to the presence of two or three large tubercles above the base of the inner margin of the movable finger. In regenerated claws of *C. virilis* the usual spines and tubercles are not always present, and then only after two or three moults. This may also be the case in *C. immunis.* Judging from the size of the unnotched claws sometimes found upon individuals of *C. immunis,* several moults have certainly taken place since the original chela was lost.

Plate III., Fig. D3 shows the chelæ, rostrum and first pair of abdominal appendages of a first-form male 71 mm. in length. The right hand shows the notch, and the left one is without it. It is noticeable, also, that the setæ are better developed on the right hand than on the left. Each carpus shows two spines; on the right meros and one inconspicuous spine on the left one. Rostrum with concave edges. Abdominal appendages slender and less curved than in typical specimens; setæ on median border.

There are some constant differences between the first and second-form males. The hand of a second-form male is always relatively much smaller than of a first-form male. It is shorter, narrower and thinner, and the spines and setæ are less developed. The following are the measurements of the chelæ of two specimens each, of first-form and second-form males:

First-form male: Length, 71 mm.; length of outer margin of hand, 33 mm., length of inner margin 31 mm., breadth 11 mm.

Second-form male: Length, 71.5 mm.; length of outer margin of hand 25.5 mm., length of inner margin 24 mm., breadth 8 mm.

First-form male: Length, 59 mm.; length of outer margin of hand 26 mm., length of inner margin 24.5 mm., breadth 9 mm.

Second-form male: Length, 61 mm.; length of outer margin of hand 19 mm., length of inner margin 18 mm., breadth 6.5 mm.

Plate III., Figs. E1 and E2 show the chelæ (natural size) of the specimens from which the first pair of measurements were taken. In general, the rostrum of the first-form male is less excavated than that of the second form. In some first-form males the rostrum is nearly plane, but it is usually slightly excavated.

The female *C. immunis* has the abdomen noticeably broader than the male, so much broader, in fact, that the sexes can be recognized at a glance by this one feature. The hand of the female is also relatively much shorter. A comparison of Figs. E1 and E3 of Plate III. will show the relative proportions of the hands of the male and female. Fig. E1 is a chela of natural size from a first-form male, 71 mm. in length. Fig. E3 is a chela, also natural size, from a female 80 mm. in length. The species are no better developed on the hand of the female than on the hand of the second-form male, but it is thick and short instead of thin and narrow.

CAMBARUS RUSTICUS, GIRARD.

Plate III., Figs. 1 to 13.

This species is widely distributed over the United States, and has been reported from several localities in Missouri. In the collection we have specimens from the Osage River, Springfield, Marshalfield, Mt. Vernon, Linn Creek, and perhaps Columbia. Several individuals of *C. rusticus* were found in a large collection of alcoholic specimens of *C. virilis* taken at Columbia, but whether they were captured with the *C. virilis* or were introduced into the collection is uncertain. The species is not common in the locality.

Faxon ('85, pp. 111, 112) suggests that under *C. rusticus, C. placidus* (Hagen), *C. juvenilis* (Hagen), and also *C. wisconsiensis* (Bundy), should be included. He says of the above mentioned species: "After a careful comparison of all the species before me, I am inclined to unite them all as forms of *C. rusticus.*"

As would be inferred from this, *C. rusticus* is subject to considerable variation. Faxon mentions variations in the chelæ, rostrum and first pair of abdominal appendages; also variations in the shape of the areola. He gives the type description of the hands, as follows: "Fingers gaping at the base, not bearded; movable finger incurved, external margin convex." However, individuals with external margin of the hand straight are not unusual." Faxon also mentions that in a collection of *C. rusticus* from Yellow Springs, Ohio, the young specimens, about 20 mm. long, have a dense beard on the inner side of the external finger, near the base. The rostra of all the individuals agree in being excavated, and in having thickened margins; but the rostra may be long or short, with or without rostral spines, and may sometimes have a median carina near the tip. Faxon speaks only of young specimens as having rostral spines. The first pair of abdominal appendages are usually straight and of medium length, but in some individuals these appendages are found to be considerably curved and longer than the type specimens. The areola is usually of moderate width, with sides parallel for a part of its length; but in some specimens the areola is narrow at a point in front of the center, and consequently its sides are not parallel.

Besides the above mentioned variations described by Faxon, the individuals which I have examined show other departures from the type description.

C. rusticus is described as having an areola equal in length to the distance of the cervical groove from the base of the rostrum; an abdomen a little shorter than the cephalothorax, and the anterior process of the epistoma blunt. In the specimens before me the areola is uniformly shorter than the distance from the cervical groove to the base of the rostrum, and instead of the abdomen being shorter than the cephalothorax, the reverse is the case; the epistoma, instead of being merely blunt, is often slightly notched.

The variations among individuals of the collection are so marked that without a series of specimens ranging from 25 to 100 mm. in length, the species would be very hard to identify. But with a series of specimens collected at the same time and place, one can not fail to see that they all belong to the same species.

With only a few individuals to study, one might easily classify members of this species as *C. medius* (Faxon), or *C. neglectus* (Faxon). In a number of characteristics *C. rusticus* and *C. medius* are identical. The features by which *C. rusticus* is to be distinguished from *C. medius* are differences in the rostra, in the length of the first pair of abdominal appendages, the relative length of abdomen and cephalothorax, and the areolæ.

In certain individuals of *C. rusticus* the rostrum is broad, without spines and with a median carina near the tip. The carina makes the rostrum answer to the description of the rostrum of *C. medius*. The chief difference between the abdominal appendages of the two species is that in *C. medius* the rami are longer than in *C. rusticus*. Whenever the rami of *C. rusticus* are a little lengthened, we have the *C. medius* form of appendage. *C. rusticus* is described as having an abdomen a little shorter than the cephalothorax, *while C. medius* is described as having an abdomen and cephalothorax of equal length; but in the specimens which I have, the abdomen is uniformly longer than the cephalothorax, so that this can not be used as a character by which to distinguish the species.

I was at first inclined to identify them all as *C. medius*. However, at the suggestion of Dr. Ayers, under whose direction I have done the work, I sent several individuals to Professor

Faxon in order to get his opinion as to what specific name should be applied to them. I sent two large ones and three small ones. Faxon classified them as two species, a thing which I think he would not have done had he had a complete series before him. His classification is *C. rusticus* and *C. neglectus.* Here again the chief features distinguishing these two species are shape of rostra and relative length of abdomen and cephalothorax; the first pair of abdominal appendages and the development of spines on the lower surface of the meros. As already noted, the rostrum is quite variable; in the specimens before me there are all gradations between the form of rostrum described for *C. neglectus* and that described for *C. rusticus.* *C. neglectus* is also described as having an abdomen larger than the cephalothorax. This is true of all the specimens before me, not only of the specimens described as *C. neglectus,* but also those described as *C. rusticus.* The first pair of abdominal appendages of the first-form male of *C. neglectus* are described as nearly straight and so long that when turned forward the tips of the rami reach the base of the chelæ. These appendages in *C. rusticus* are also nearly straight, but are only long enough to reach to the base of the second pair of legs. A slight decrease in the length of the rami of *C. neglectus* is all that is necessary to reduce them to the *C. rusticus* form. In one of the specimens that Faxon classified as *C. neglectus* these appendages are no longer than demanded by the description of *C. rusticus.* In *C. neglectus* the lower surface of the meros is described as having two rows of spines; in *C. rusticus* all of these inferior biserial spines are described as only slightly developed, except the apical one of each row. More often than not, these spines in the species described as *C. neglectus* are reduced to low blunted tubercles, thus bringing them to the *C. rusticus* form. There is one more point that should be mentioned, viz.: in *C. rusticus* the antennal scale is described as slightly longer than the rostrum, while in *C. neglectus* the antennal scale is described as equal in length to the rostrum, but in the individuals described as *C. rusticus* the antennal scale is sometimes no longer than the rostrum; so that feature is also useless as a means of classification.

Since in the eighty-five individuals which I have before me not a single character that would separate them into *C. rusticus* and *C. neglectus* is found to hold throughout, we must conclude that they are all variations within one species. If I had only the extremes to judge from, I should not hesitate to separate them into two species. However, the general contour of the body and the general form of the first pair of abdominal appendages of the male remains constant throughout the series. This, together with the fact that all of these varying gradations are found among individuals that have spent their lives in the same stream, and when they were collected were captured at the same time, seems to indicate that whatever these variations may lead to in the future, they should now all be included under one species.

That these variations form a graded series in which there is no definite dividing line, I have attempted to show by means of the photographs reproduced in Plate VI.

These photographs show a series of the differences in form of chelæ, rostra and general body contour typical of the collection. It is evident that in a series such as this it is not permissible to say that a certain number of these individuals should be classed as one species and the rest as another.

Plate VI., Fig. 1 is one of the specimens which Faxon classified as *C. neglectus*. According to the same classification, Figs. 2, 8, 9, 11, 12 and 13 would also be called *C. neglectus*. Figs. 3, 4, 5, 6, 7 and 10 would be classed as *C. rusticus*. Figs. 4, 9, 12 and 13 are females; the remaining specimens are males.

In looking over the figures shown in Plate VI. no one will deny that there are some differences which at first sight may appear conspicuous, but these differences are not characteristic. We look at the crayfish called *C. neglectus*, and decide that a certain form of chela is characteristic; but on the crayfish classed as *C. rusticus* we find the same sort of chela. If any other character be selected we find the same difficulty. Not a single individual can be found that exactly accords with the description of either species.

Since this is the case, and since *C. rusticus* is an old species, it having been nearly half a century since Girard named it, I have, as was mentioned above, classified the whole series under *C. rusticus*. The species *C. medius*, which I shall take up next, seems to me to belong under *C. rusticus* also.

CAMBARUS MEDIUS, FAXON.

C. medius has been reported only from Missouri, and from but one locality, Irondale. The only specimens which are known to have been collected are the two from which Faxon named this species. The likenesses and differences between this species and *C. rusticus* have already been mentioned in discussing *C. rusticus*. As has been shown, the differences which separate the three species, *C. rusticus*, *C. neglectus*, and *C. medius*, are very slight and inconstant. Knowing, as I do, the variability of the individuals within the species *C. rusticus*, and considering the fact that Faxon had but two specimens from which to name the species *C. medius*, it seems to me quite probable that those individuals which Faxon calls *C. medius* are variations of *C. rusticus;* and I think that he would have recognized them as such if he had been able to examine a number of individuals.

I think that a careful comparison of the descriptions of these three species, together with an examination of the variation within the one species *C. rusticus*, proves that not a single feature which would distinguish one species from another holds through a single series of specimens taken at the same time and place. If one character — *e. g.*, relative lengths of abdomen and cephalothorax — tells in favor of identifying the specimen as *C. rusticus*, some other character — *e. g.*, length of first pair of abdominal appendages—answers to the description of *C. medius*. In not a single individual that I have examined have the main distinguishing characteristics between these three species been united. It is clear that such extremely variable characters have not the value of specific characters.

Within the species of which I have had abundant material to examine *(C. virilis)*, there are greater and more numerous variations among individuals coming from the same pond than are used to separate the three species, *C. rusticus*, *C. neglectus* and *C. medius*.

CAMBARUS VIRILIS, HAGEN.

Plates I. and II.

For synonomy see Faxon (loc. cit. p. 96).

C. virilis is the most common species in the state. It is found in great numbers wherever it occurs, and it is widely distributed. It has been collected from the following localities in Missouri: St. Louis, Osage River, Irondale; Washington, Franklin County; Kansas City; Niangua River, Camden County; Marmaduke, Lawrence County; Linn Creek and Columbia, Boone County. Most of the above named places are situated in the central and southern part of the state.

C. virilis is especially plentiful in the ponds and streams about Columbia. Upon one occasion in June, 1896, Dr. Ayers collected in the course of two and a half hours more than five hundred crayfish of this species. There is one lot in our present collection which contains over twelve hundred individuals. The whole collection of *C. virilis* contains over three thousand specimens. In general the number of females collected exceeds the number of males; although in one or two lots in the collection the males are in excess of the females. In one lot, taken at Columbia in 1897, there are 162 males and 203 females. Among 212 crayfish collected during April, 1899, 80 were males and 132 were females. In most collections the males and females are in about the above proportions.

The abundance of *C. virilis* renders it an excellent subject for the study of variations within a species, and for a comparison of the differences between the first- and second-form males.

A special discussion of second-form males will be taken up later. Here it may be mentioned that, besides the difference in the form of the first pair of abdominal appendages, which separates the males into first and second forms, there are other noticeable differences between the two forms. Especially noticeable is the difference in the relative size of the chelæ. The first-form individuals of the same size. A comparison of the chelæ of the second-form individuals are much smaller than in Figs. K and L of Plate I. shows this difference. Fig. K is full and broad, and with outer margin of hand considerably curved. The spines and tubercles are well developed. In Fig. L the hand is thinner and narrower, and the outer margin is nearly straight. The spines and tubercles are less developed than in Fig. K. The crayfish from which Fig. K is taken was 67 mm. long, and the one from which Fig. L is taken was 68 mm. long.

A still more remarkable difference is seen between Figs. N and O of Plate II. The crayfish from which the former is taken was 74 mm. long, and the one from which the latter is taken 78 mm. long. There was no great difference in the size of the two animals, but a very marked disparity existed in the size of the two chelæ. The figures are life-size in all cases. For Fig. N the measurements of the hand are: length, 23 mm.; breadth, 9 mm. For Fig. O: length of hand, 39 mm.; breadth, 14 mm. These two chelæ also show a more marked difference in the development of the spines than Figs. K and L.

Immature C. virilis: Even in very young individuals and chelæ.
C. virilis presents a number of variations. The variations here, as in older specimens, are to be noticed mainly in the rostra

As is well known, the newly hatched crayfish is in some particulars very different from the adult individual, and it will be necessary to speak of some of these differences first.

When the little animal first comes from the egg the cephalothorax is very large in proportion to the abdomen. The abdomen, thoracic legs and the antennæ are flexed under the almost spherical cephalothorax. The different parts of the cephalothorax can not at this time be distinguished. The rostrum is very short and bent down between the eyes; the chelæ present very little of the appearance of the chelæ of the adult. The beginning of the suture which is to form the joint of the movable finger is only visible under considerable magnification; the tips of the chelæ are furnished with recurved hooks; this is also true of the other chelate appendages, but their hooks are not so strongly recurved as in the chelæ.

With a magnification of one hundred diameters small spines and setæ are visible on various parts of the exoskeleton.

No appendages are present on the first and sixth abdominal somites; however, the appendages of the sixth somite are already formed and inclosed beneath the telson, from which they are set free after the animal moults.

The crayfish when first released from the egg is quite helpless, and it remains attached to the swimmerets of the mother for some time. The muscles are still in an embryonic condition.

Within five or six days a considerable development has taken place, although no moult has intervened. The animal is able to swim about; the relative size of the cephalothorax is not nearly so great. The remnant of food yolk which was stored up in the cephalothorax has diminished considerably, and now, instead of forming a continuous mass, has separated into two masses, one on either side of the median line, with a clear space between. The cervical groove and areola area can now be distinguished. The spines and setæ are much better developed than when the crayfish came from the egg.

In about nine days after hatching the first ecdysis occurs. At this time the telson fins are set free, and the spines and setæ show a marked increase in size. The rostrum is much lengthened, and is no longer bent downward between the eyes; small rostral spines have made their appearance. The chelæ have lost their recurved hooks. The abdomen and cephalothorax have assumed about the same relative proportions as are found in the adult. The appendages of the first abdominal somite have not yet appeared, although a minute swelling under the skin can be seen, and the appendages will be set free after the next moult. The animal at this stage measures 7 to 8 mm. I have seen these appendages on *C. gracilis* 15 mm. long. The appendages had evidently just appeared, for previous to this they were simple little buds, without any differentiation into segments. At 18 mm. there is a separation into protopodite and distal portion of the appendage, but no division indicating a separation into endopodite and exopodite. Whether these appendages appear earlier or later in *C. virilis*, I do not know, having had no specimens of this species to examine; but I think it probable that *C. virilis* would be somewhat larger, since the adults in *C. virilis* are of somewhat greater size than *C. gracilis*.

After the first moult the young crayfish do not yet leave the protection of the mother, but either attach themselves to or detach themselves from the swimmerets of the female, as suits the occasion.

A small part of the food yolk still remains, but in four or five days after the ecdysis it has all disappeared, and the little animal must then shift for itself.

At this stage the young crayfish are almost transparent, and by placing a live one under the microscope the circulation of the blood in the gills, the beating of the heart and the passage of the water through the gill chambers may be observed. From the ventral side can be seen the double nature of the nerve cord through the length of the abdomen and a part of the cephalothorax.

The areola is relatively broader in the young crayfish than in the adult. A crayfish about nine days old, 8 mm. long, has an areola .3 mm, wide; that is, the breadth of the areola is to the length of the animal as 1 to 27; a crayfish 68 mm. long has an areola about 1 mm. wide; thus the relative length of body and areola is as 1 to 68 in the adult.

The gill system of the newly hatched crayfish appears to be identical with that of the adult. I have examined a number of crayfish just from the egg, and in no case have I been able to discover any trace of a gill on the last thoracic somite.

I was enabled to make these observations on the very young by taking females in berry and hatching the eggs in the laboratory; thus far I have succeeded in studying them from the time of hatching through the first moult.

At this very young stage but little variation can be noted. By the time they are 9 or 10 mm. long, variations are conspicuous. One of the most noticeable points of difference at this stage is seen in the length and shape of the rostrum. Some of them show rostral spines by the time they are 10 mm. long, others show no signs of these spines; but then we often find mature *C. virilis* devoid of rostral spines, and it may be that the adult individuals, instead of having lost these spines in the course of development, have never possessed them.

At 9 or 10 mm. the chelæ show nothing particularly characteristic of *C. virilis*, but variations in the relative proportions of the appendages are already present.

By the time the young animal is 18 mm. long, the chelæ show a characteristic which is one of the most constant of the species, namely, the smooth, thickened margin on the outer contour of the hand. This margin is always present in a regenerated claw; after the first moult, and so far as my experience with the species goes, it is the only characteristic that may be considered absolutely constant.

There is some variation in relative lengths of abdomen and cephalothorax. The following is a table of measurements taken from individuals varying from 35 to 45 mm. in length:

LENGTH OF BODY	LENGTH OF ABDOMEN	LENGTH OF CEPHALOTHORAX
35.00 mm.	20.10 mm.	15.00 mm.
44.00 "	24.00 "	20.00 "
44.00 "	23.00 "	21.00 "
40.00 "	21.50 "	18.50 "
35.00 "	18.50 "	16.50 "
44.00 "	24.00 "	20.00 "
43.00 "	23.00 "	20.00 "
44.00 "	22.50 "	21.50 "
42.00 "	22.00 "	20.00 "
42.00 "	22.00 "	20.00 "

It is to be noticed that these variations are not so marked as those found in *C. gracilis*, although in other respects *C. gracilis* is by far the more constant species. In *C. virilis* the abdomen is in every case longer than the cephalothorax.

Much greater variation is found among adults of *C. virilis* than among the young; even though they have been collected in the same vicinity, out of the same pond or creek.

Following are the descriptions of a number of figures which show the variations in rostra, chelæ and first pair of abdominal appendages of the male.

Plate I., Fig. A shows the chelæ, rostrum and first pair of abdominal appendages of a first-form male 106 mm. in length, taken at Columbia. The hand is long, thin and very spinous, and with outer contour very much curved. The carpus has two well-defined spines on the median border. The meros two spines on its upper border. The rostrum is long and narrow, with the rostral spines almost obsolete. The abdominal appendages have three well defined tufts of setæ arranged along their inner borders. The tufts of setæ on the lower projection is very unusual.

Plate I., Fig. B shows chela, rostrum and first pair of abdominal appendages of a first-form male 80 mm. long. This individual was also taken at Columbia. The general outline of the hand is much the same as in Fig. A, but the spines are not so well developed and the hand is not so thin. There are three instead of two spines on the upper border of the meros. The rostrum is especially noticeable on account of its many angles. This form of rostrum is not common. The abdominal appendages have only two tufts of setæ, and are not so much curved as in Fig. A.

Plate I., Fig. C shows chela, rostrum and first pair of abdominal appendages of a first-form male 71 mm. long, collected at Columbia, 1895. This shows a hand relatively much shorter and thicker than the previous specimens. The spines are much less developed than in Figs. A and B; the distribution is about the same, except that on the meros there is but one spine, and that one small. The rostrum is short and broad, with an obtuse apex and no spines. The abdominal appendages are thicker compared with their length than in the preceding specimens.

Plate I., Fig. D shows chela, rostrum and first pair of abdominal appendages of a first-form male 82 mm. in length, taken at Columbia, 1895. The hand is long and thin, the spines small and the movable finger crooked. The carpus has three spines on its inner border, and the meros has but one on its upper border. The rostrum is of medium length, the sides almost parallel and the acumen acutely angular. The abdominal appendages are relatively long and slender, and show but one well developed tuft of setæ.

Plate I., Fig. E shows chela, rostrum and first pair of abdominal appendages of first-form male 91 mm. in length. The hand is long and thin, the opposable edges of the fingers bordered by large, blunted spines. On the median border of the carpus is a very large spine and one small one; on the upper surface is a group of three small spines. The meros has two spines on its upper surface. The rostrum is long and narrow, with convex apex, and entirely destitute of rostral spines. The abdominal appendages are long, slender, and less curved than in some individuals; they show two tufts of setæ, one on the lower median projection, which is not at all common in any species with which I am familiar.

Plate I., Fig. F shows rostrum and first pair of abdominal appendages of a second-form male 102 mm. long, taken at Columbia in the same collection as Figs. C, D and E. No normal chelæ were present, which is the usual state of affairs in a large second-form male. The rostrum is long, with sides slightly concave, and with the base very little broader than the distal end; sides of the apex also concave, acumen sharp-pointed, with small median carina. The abdominal appendages are long, slender and considerably curved.

Plate I., Fig. G shows rostrum and first pair of abdominal appendages of a second-form male 98 mm. long. This is also from the same collection as Fig. F, being short, almost triangular, with a very broad base, and with an extremely acute acumen, and with conspicuous rostral spines. The abdominal appendages are not so strongly curved or so slender as in Fig. F.

Plate I., Fig. H shows chela, rostrum and first pair of abdominal appendages of a first-form male 98 mm. in length, belonging to the same collection as the preceding figures. The hand has a strongly curved external margin, and the inner margin of the fingers are widely gaping and bordered by well developed, blunted spines. The carpus is furnished with two sharp spines on its median border. The meros has but one spine on its upper surface. The rostrum is triangular, of medium length, and has a very sharp apex. The abdominal appendages are long, much curved, and show two tufts of setæ on median borders.

With the exception of the first two above described figures (Figs. A and B), all of the individuals from which these figures were drawn were collected in the same vicinity during the same year. The specimens from which Figs. A and B were drawn were collected in the same vicinity, but not during the same year. These crayfish had passed their lives under practically identical conditions, and yet present marked variations. Still each individual presents enough of the characteristics of the species to make it certain that they all belong to the same species, wide apart as the extremes are, for there is a closely graded series of intermediate stages. Crayfish from different localities within the same state also show variations, but not more marked than those which are to be seen among individuals of the same locality.

I have had no opportunity to examine an extensive series of the same species coming from different states; but it seems reasonable to suppose that these might show variations different from those among individuals of practically the same locality.

Following is a further description of the variations of *C. virilis*, all of which were taken in Missouri.

Plate I., Fig. I shows chela, rostrum and first pair of abdominal appendages of a second-form male 74 mm. long, taken November, 1898, at Columbia. The hand is small and the spines adorning it are small; both are relatively much smaller than the hand and spines of a first-form male of the same size. The rostrum is long, with parallel sides, a very sharp acumen and no lateral spines. The abdominal appendages are slender and straight, with curved tips.

Plate I., Fig. J shows chela, rostrum and first pair of abdominal appendages of a first-form male 62 mm. in length, taken at Columbia, November, 1898. Hand is relatively much thicker than that of the second-form male shown in the preceding figure; the spines are also much better developed. Movable finger is considerably curved; carpus with one very prominent spine and two smaller ones; meros with two sharp spines on upper surface. Rostrum triangular, with sharp-pointed acumen. Abdominal appendages with a gradual curve throughout their whole length.

Plate I., Fig. K shows chela, rostrum and first pair of abdominal appendages of first-form male 67 mm. long, taken at Columbia. External border of the hand strongly curved, spines small. Carpus with two well developed spines on median border; a row of small tubercles on the upper surface. Two small spines on the upper surface of meros. Abdominal appendages more slender and less curved than in Fig. J.

Plate II., Fig. L shows chela, rostrum and first pair of abdominal appendages of second-form male 68 mm. in length, taken at Columbia. Hand small and their spines small. Carpus with one large and two small spines on internal border. Meros with two inconspicuous spines on its upper surface. Rostrum long, with parallel sides and very sharp acumen. Abdominal appendages slender and straight, except at the tips.

Plate II., Fig. M shows chela, rostrum and first pair of abdominal appendages of a first-form male 111 mm. in length, taken at Columbia, March, 1897. This figure should be compared with Plate I., Fig. A, for both crayfish were taken from the same pond at the same time. The hand is very large and thick, with a much curved external border; opposable edges of the fingers bordered with large, blunted tubercles. Carpus with one long and two short spines on median border, and with small tubercles scattered about on the upper surface. Meros with well developed spines on the upper surface. Rostrum large, with parallel sides, median carina in distal third, rostral spines almost obsolete, acumen sharp and long. Abdominal appendages long and slender, with three tufts of setæ. As was mentioned in connection with Fig. A of Plate I., the tufts of setæ on the lower median projection is quite unusual in this species.

Plate II., Fig. N shows chela, rostrum and first pair of abdominal appendages of a second-form male 74 mm. in length, taken in Camden County, March, 1897. Hand very small and straight, with very small spines. Carpus with well developed spine on the median border. Meros with two small spines. Rostrum short, broad, triangular, with obtuse acumen. Abdominal appendages straight and slender, setæ very inconspicuous.

Plate II., Fig. O shows chela, rostrum and first pair of abdominal appendages of a first-form male 78 mm. in length. Hand large and thick, with external border much curved, tubercles and spines well developed. Carpus with two well developed spines on median border. Meros with two small spines on upper surface. This chela shows a marked difference from the one shown in Fig. N of Plate II.; although there is very little difference in the size of the crayfish from which the two were taken; and it should be added that the two individuals were found at the same time and place. The rostra in Figs. N and O are very similar. The abdominal appendages are much alike, except that those shown in Fig. O are much more curved than those shown in Fig. N.

Plate II., Fig. P shows chela, rostrum and first pair of abdominal appendages of a first-form male 110 mm. long, taken at Mt. Vernon, Lawrence County, April, 1897. Hand very long and thin, with small spines, outer margin straight and upper surface flat. Carpus with two well developed spines on median border. Meros with two small spines on upper surface. It is probable that this chela is a regenerated one, for I have seen this same form of chela on one side of the body, while on the other side the chela was large and thick, but on the specimen from which this figure is taken both chelæ were of the same character and of about equal size. There were also several other individuals of the same collection which had chelæ like these. The difference is so very marked that one would, unless he had thick-clawed individuals at hand, be tempted to classify the thin-clawed ones as something other than *C. virilis*. Rostrum broad, with almost parallel sides, and with obtuse acumen. Abdominal appendages long and slender, without conspicuous setæ.

Plate II., Fig. Q shows chela, rostrum and first pair of abdominal appendages of a first-form male 110 mm. long, taken at the same time and place as that of Fig. P, Plate II. Hand very large and thick, with much curved external border, spines well developed, opposable surfaces of the fingers bordered by large, blunt tubercles. This hand is markedly different from the hand in Fig. P. Carpus with two sharp spines on internal border. Rostrum shorter and narrower than in Fig. P. Abdominal appendages shorter and not so slender as in the preceding figure.

Plate II., Fig. R shows chela, rostrum and first pair of abdominal appendages of first-form male 82.5 mm. long, taken at Columbia. Hand short and relatively very thick, movable finger crooked. Carpus with one short spine and one very small one on median border. Meros with three spines on upper surface. Rostrum with concave edge and sharp acumen. Abdominal appendages relatively thick, slightly curved, and with two tufts of setæ.

It will be noticed that all the above described variations have been found among individuals within this state and in only three different localities. Individuals from other localities might also have been chosen, but from these three I was enabled to select all the representative variations that are shown in the collection.

FIRST AND SECOND FORMS.

Since the publication of Hagen's " Monograph of the North American Astacidæ," we have known of the existence within each species of Cambarus of two distinct forms or varieties of the males. This variation finds expression in the shape of the first pair of abdominal appendages. In consequence of this the males are usually designated as *first-* and *second-*form males.

The first pair of abdominal appendages in the second form are similar to the same pair of appendages in the young, immature males. In the first-form males these appendages have the distal terminations much more slender, and often fine pointed instead of blunt, as is always the case with the distal terminations in the second form.

The fact that the second-form appendages have the same general form as the appendages of the immature males led to the supposition that the second-form males are sterile. Faxon states that the testes are smaller and the vasa deferentia shorter in the second form than in the first. He also suggests that these two forms are alternating conditions in the life of the same individual, the first form being acquired during the breeding season and the second form during the other seasons. These changes, of course, can not take place without intervening moults, but Faxon really observed that some crayfish which he had in a tank moulted from first-form into second-form. However, he did not carry his observations far enough to determine when, if ever, they again reverted to the first form. Neither has he offered any explanation as to a probable cause of the change from one form to the other.

The fact that a first-form male will moult into a second-form precludes the idea that the second form in any true sense represents a developmental stage in the individual. Also the fact that we often find in *C. virilis* and *C. rusticus* at least small first-form males 40-45 mm. long, living side by side with second-form males 80-100 mm. long, shows that the size of the individual bears no relation to the condition of first or second form. Hence an explanation must be sought elsewhere.

During the past two years, in the course of my taxonomic studies, I have had occasion to examine a great many males of each form, especially of the species *C. virilis*. This abundance of material has given me an opportunity to make very complete observations on the two forms.

In looking over alcoholic specimens, I noticed that whenever I found a large second-form male, 80-95 mm. long, that it never had perfect, well developed chelæ. There were either no chelæ, or the chelæ present were in a very imperfect state as regards size and sculpture, indicating that they had been lost and were now being regenerated. Finding this uniformly the case, I was led to surmise that the existence of first and second forms is connected with the presence or absence of chelæ. It will be remembered that the chelæ of the second-form males are always described as smaller and with smaller spines and tubercles than those of first-form males of a corresponding size.

On April 22, 1899, I took a number of large first-form males and broke off both chelæ, expecting them soon to moult into second-form individuals. In this I was not disappointed, for during the next two or three weeks several of them moulted, each one into a second form. However, I noticed a difference between the second-form with chelæ and the second-form without chelæ. The first pair of abdominal appendages of those with chelæ are not so slender; they are as individuals without chelæ. The basal half of the appendage has the usual shape of the first-form appendages, and although the rami are blunt, as is usual with the second-form, they are not so closely approximated, and the tip of the inner ramus is more dilated than in the second form without chelæ. (Plate IV., Figs. A and C.) The appendages shown in Fig. A are from a second-form male without chelæ, and the appendages shown in Fig. C are from a second-form male with chelæ.

When it was found that the crayfish, whether with or without chelæ, and whether first- or second-form, all moulted into second-form, it became evident if there were to be first-form males the next year, there must be a second moulting season during the summer. For in every case that I have been able to observe, a male that is already second-form in the spring, moults again into second-form. But, as I stated above, these are individuals that have no chelæ at all, or only imperfect ones.

That there are really two moulting seasons I had already suspected; for while engaged in doing some experimental work upon crayfish, I found that usually the animal moulted in April or May, and again between the first of June and the last of August. However, I was not sure that mutilation did not increase the frequency of the moults. But my observations between May first and the middle of July, 1899, proved that normally each male crayfish moults at least twice a year. The time from March to November will include both moulting seasons for *C. virilis*.

The first moulting season begins in April, and by the middle of May very few crayfish can be found that have not recently moulted. During the first moulting season all the males moult into second-form. However, all the males with large chelæ have the bases of the first pair of abdominal appendages meeting in the median line, while those males with small chelæ, or with no chelæ, do not have these appendages meeting in the median line. (Plate IV., Figs. B and F.) The difference in shape and development of the bases, and in the general sculpture of the appendages, is noticeable in Figs. B and F. In Fig. F the appendage has much more of the general appearance of a first-form appendage than in Fig. B.

The fact that all males moult into second-form during the first moulting season accounts for the great number of second-form individuals that are taken at some seasons, while comparatively few are taken at other times. Males from collections made in May are likely to be mostly second-form. But collections made after the first of July will contain a relatively small number of second-form males. We have one collection made in early June that contains over seven hundred and fifty second-form males and only five first-form. In the collections made in the spring of 1899, before May first, not more than six or seven second-form males were taken, and they were all of medium size. From the tenth of May to the tenth of June the collections contained very few first-form males.

By the tenth of June the second moulting season is well begun, and by the first of July comparatively few second-form males are to be found. Although now and then on through July and August a moulting specimen may be found.

Having found that all the males, whether large or small, moulted into the second form during the first moulting season of the spring, I expected to find that at the second moult the males with chelæ would again be transformed into first form, while those without chelæ would retain the second-form appendages after the second moult. That such is really what happens, my observations have verified; in every instance males possessed of two or even one well developed chela, have at the second moulting returned to the first form, and those without chelæ have retained the second-form appendages after the second moult.

This appears to be conclusive evidence that the relation between the chelæ and first pair of abdominal appendages is such a close one that the loss of chelæ will produce a change in the form of the sexual appendages which is more or less permanent. In other words, a first-form male that loses its chelæ before or at the time of the first moult, will at the second moult still retain the second-form appendages; a crayfish that loses its chelæ after the first moulting season of any given year, but before the second moulting season, may or may not moult into the second-form again at the second moult, depending upon how near the second moult is at hand when the chelæ are broken off. A male having once lost its chelæ will continue to moult as second-form until the new chelæ have attained a considerable size.

In a collection of crayfish brought into the laboratory this spring, May 10, 1900, I found one about 77 mm. long that had recently moulted into second-form, and with both chelæ missing. The stumps of the chelæ were quite smooth, and no signs of the regeneration of these appendages had yet appeared. Quite likely the chelæ had been lost during the last moult, which had evidently taken place only a few days before. May 13th, three days after I had found this crayfish, it again moulted into second form. At this moult there was only the rudiment of a new chela. A minute bud had appeared, which showed no semblance whatever to an appendage. Then on June 17th this crayfish moulted for the third time, still retaining the second-form appendages. Between the last two moults, May 13th to June 17th, the chelæ had grown to such an extent that when they were released from the confining skin at the third moult, they expanded to more than an inch in length.

August 10th this crayfish died without having moulted again. At the time it died the chelæ measured 36 mm. in length and 5 mm. in width, this entire growth having been made in three months.

Judging from the small, imperfectly developed chelæ which I have seen on the other second-form individuals, I think it scarcely probable that, had this crayfish lived through another moult, it would have then reverted to first-form, for the chelæ would still not have been so large as it appears requisite for them to be in order that the crayfish be first-form. For it is well known that the growth of the chelæ is quite slow after the moult in which the chelæ first appear in the form of true jointed appendages. Plate IV., Fig. K, shows the chelæ, natural size, of the crayfish described above. Although this growth took place within three months, most of it occurred between May 13th and June 17th, very little over a month. The chelæ were only 36 mm. long when the crayfish died, August 10th; they were fully 33 mm. long June 17th. Only a minute bud had appeared between May 13th and June 17th, and only 3 mm. between June 17th and August 10th, an interval almost twice as long.

From the above consideration it is readily seen, on the hypothesis that absence of chelæ is the cause of a crayfish remaining second-form through two or more successive moults, that it is altogether possible that a crayfish remains second-form through several moults — *e. g.*, four or five at least. We have positive evidence that they can and do remain second-form through three successive moults when the chelæ have been broken off, and that when chelæ are present, the crayfish alternate from first-form to second-form with each moult.

I might here add that *C. gracilis* furnished some negative proof that loss of chelæ perpetuates second-form males. Faxon states that second-form individuals among *C. gracilis* are unknown. There are two facts to be noticed which help to explain this absence of the second-form in this species. First, as I have mentioned in discussing the species, their moulting season has never been discovered, and there are, at most, only a limited number of males in any collection. Of course, the fact that the time of moulting is unknown does not explain why the second-form has not accidentally been found instead of always first-form. But the extreme scarcity of the males may help to explain this.

The second fact to be noticed in this connection is that *C. gracilis* never shows that there has been a loss of parts, as chelæ or other appendages. When individual *C. gracilis* are first captured, no appendages are broken except those which show evidences of having been broken in capturing them. Now the only grounds upon which I attempt to explain this are, that the external conditions to which the animals are subjected are such as favor a minimum of accidents. Living in their burrows as they do, it seems that they are able to avoid many misfortunes which come upon other species of crayfish that habitually live in the streams and ponds. In none of the collections of *C. gracilis* which I have seen has there been an individual with a broken chela, unless there was evidence that it had been recently broken. Since none have moulted in my laboratory, of course there is no way of determining whether they moult into second-form or not, or whether breaking off the chelæ would cause them to moult into second-form. From what we known of other species of Cambarus, it is fair to suppose that males of *C. gracilis* normally have two moulting seasons; at the first, moulting into second-form, and at the second returning to first form.

Experiments have proven that young *C. gracilis* repair an injury and regenerate a lost or broken appendage as readily as the young of any other species. And though they are seldom injured, they seem not to have lost in the least the power of regenerating lost parts. My observations and experiments on this species have been confined to young specimens, 35 or 40 mm. in length.

It is not unusual to find first-form males without chelæ, but either only bare stumps are present, or the new growth that has occurred shows that no moult has taken place since the chelæ were broken off. It is quite probable that the chelæ were broken off during the last moult; for it often happens that a crayfish loses one or more appendages in his efforts to free himself from his old shell.

The loss of but one chela does not seem to sufficiently derange the mechanism of the animal to change it from first to second form. However, in a number of instances I have found indications that the loss of one chela affects the reproductive organs.

During March and early April, in making some dissections, I noticed in two instances where one chela was missing; that on the opposite side of the animal the vas deferens was much shorter than on the side from which the chela was gone. Having noticed this difference in two instances, I dissected a number of other crayfish with but one chela, and in every case where it was evident that the chela had been lost for some time I found this same difference between the reproductive organs of the two sides. The shortening of the vas deferens was always on the opposite side from the missing chela, irrespective as to whether it was the right or left chela.

For comparison I examined a number of other males having both chelæ present. Without exception I found the vasa deferentia equally developed on each side. Had I found this difference between the vasa deferentia of males with two chelæ and males with one chela to remain constant for all seasons of the year, I should have considered it positive proof that the loss of the chelæ is directly connected with the degeneration of the reproductive organs. Although I found this to be true for every case examined during the latter part of March and early April, in June, when I came to examine males with but one chela, this difference was no longer apparent. I can offer no explanations for these facts as yet.

It is well known that the reproductive organs vary considerably in size and development at different seasons of the year, being larger and better developed during late summer and early autumn, just before and at the time of the breeding season than at other times of the year. There is also known to be a difference in the relative development of the testes and vasa deferentia of the first- and second-form males, but this difference is much more conspicuous during some seasons of the year than others.

During the last few days of March, 1899, and the first two weeks of April, I examined the reproductive organs of both first- and second-form males. This was done before the first moulting season began. For comparison I took them in pairs, a first-form and a second-form of the same size. In each instance I found a marked difference between the reproductive organs of the two, especially of the vasa deferentia. In the first-form the vasa deferentia were always much convoluted, while in the second-form these organs were usually straight, having at most not more than one or two convolutions.

About the first of May I again examined a number of crayfish that had passed through the first moulting season. Then, as before, I found that males having the first pair of abdominal appendages thick, with rami gaping and tip of inner ramus dilated, indicating that the animal was of the form that would moult into the first-form at next moult, invariably had much convoluted and well developed vasa deferentia. Males whose first pair of abdominal appendages were slender, indicating that they were of true second-form, had in every case unconvoluted vasa deferentia.

In early June, after the beginning of the second moulting season, I again examined first-form and second-form males. Although I found that the shape and size of the testes and the convolutions of the vasa deferentia of different individuals varied considerably, I did not find, as I had previously, that the reproductive organs of the second-form males were much less developed than those of the first-form males. (Plate IV., Figs. D and B.) Neither was there any constant difference in the shape of the testes of the first-form and second-form males.

If it is true, as my first observations seem to indicate, that a loss of the chelæ results in a reduction in size of the reproductive organs, then a male that loses its chelæ at second moult — that is, when it moults from second-form into first-form — should after a time show a degeneration of the reproductive organs. Proceeding on this hypothesis, I took, June 27th, a first-form male 90 mm. long, that had lost its chela in the last moult, nearly three weeks before, and for comparison a first-form male of the same size, with the chelæ present, and found that the vasa deferentia of the one with chelæ were no better developed than those of the one without chelæ. However, the testes were larger and better developed. A microscopic examination showed that the testes of the one with chelæ were filled with spermatazoa in an advanced stage of development, while the testes of the one without chelæ contained very few spermatazoa, and these few were in the early stages.

The reproductive organs from another pair somewhat larger, otherwise similar, individuals were then examined. So far as size was concerned, there was very little difference in the reproductive organs of the two individuals; but microscopic examination again showed great numbers of spermatazoa in advanced stages in the vasa deferentia and testes of the one with chela, and practically no spermatozoa at all in the vasa deferentia and testes of the one without chelæ.

I then examined the reproductive organs of a first-form male 98 mm. long, that had had the chelæ taken off April 22d, about two months before, and had been in the laboratory since that time without moulting. Apparently the testes were much degenerated; they were small and semi-transparent. (Plate IV., Fig. J.) But the vasa deferentia were large and convoluted; at the ends near the external openings they were opaque and milky looking. A part of the distal end of a vas deferens was examined, and found to be filled with spermatozoa of advanced stages.

Whether or not the testes were permanently degenerated could not be decided. Certain it was that at that time they presented an unnatural appearance. The fact that the vasa deferentia were full of spermatozoa does not argue for the active, healthy condition of the testes, for it is well known that in many animals the spermatozoa retain their vitality for long periods, and these spermatozoa which filled the vasa deferentia of this crayfish may have been in the vasa deferentia for a long time.

Although I consider it a well-established fact that presence or absence of chelæ determines whether an individual male crayfish is to be first or second form, yet at the present there appears no way of determining whether the second form is sterile or not.

SUMMARY.

1. The examination of thousands of specimens of the species *C. virilis* has led to the conclusion that there are greater

variations within this one species than are often used to separate individuals into different species, and the variations involve the characters used for classification.

2. In view of the extremely diverse variations found within the species *C. rusticus* (Girard), it is desirable to include the recently described species *C. neglectus* (Faxon) under *C. rusticus*, since the variations found within this last named species include every characteristic that could be used to separate the two species.

3. Relative lengths of cephalothorax and abdomen, length of first abdominal appendages of the male, presence or absence of spines, shape of chelæ and rostrum, can not be relied upon as specific distinguishing characteristics; *e. g.*, *C. virilis* shows almost every shape of rostrum described within the genus Cambarus.

4. Two new species, *C. ayersii*, Group I., and *C. whitmani*, Group IV., are described for the first time.

My work upon the second-form males has led me to the following conclusions:

1. Normally, in *C. virilis* at least, every adult male moults in the spring into second-form.

2. In the course of six weeks or two months all adult males in possession of normal chelæ moult a second time, and revert again to first-form.

3. Males without chelæ or with only imperfect ones also moult a second time during the same season, but still retain the second-form appendages.

4. Males without chelæ or with imperfect ones continue to moult into second-form until the chelæ have reached a size normal for the size of the animal.

5. In late fall and during winter and spring there is a noticeable difference between the reproductive organs of the first-form and second-form males, the testes and vasa deferentia of the second-form males apparently being much less developed than the same organs in the first-form males.

6. During the summer, though the reproductive organs of different individuals show great variation, there are no distinguishing characteristics by which the reproductive organs of first-form and second-form males can with certainty be distinguished.

7. Though there is some evidence in favor of regarding second-form males as sterile, there is as yet no positive proof of it.

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EXPLANATION OF PLATES.

Plates I. and II.

The figures in Plates I. and II. each show chela, rostrum and first pair of abdominal appendages (male) of individuals of the species *C. virilis.* In each figure the parts from one individual are grouped together in the same order.

Fig. A — A*c*, chela; A*r*, rostrum; A*a*, abdominal appendages. The letters *c*, *r* and *a* apply to the same parts in each figure on the plates.

In Plate I., Figs. A, B, C, D, E, H, J and K are taken from first-form males. Figs. F, G, I and L are taken from second-form males.

In Plates II., Figs. M, O, P, Q and R are taken from first-form males. Fig. N, from a second-form male.

Plate III.

Figs. A1 to A5 inclusive show a developmental series of the first pair of abdominal appendages of the male *C. gracilis.*

Fig. A1, from an individual 23 mm. in length.

Fig. A2, from an individual 27 mm. in length.

Fig. A3, from an individual 33 mm. in length.

Fig. A4, from an individual 40 mm. in length.

Fig. A5, from an individual 67 mm. in length.

Figs. B1 to B8 inclusive show a developmental series of the annulus ventralis of the female *C. gracilis*.

Fig. B1, from an individual 20 mm. in length.

Fig. B2, from an individual 23 mm. in length.

Fig. B3, from an individual 27.5 mm. in length.

Fig. B4, from an individual 30 mm. in length.

Fig. B5, from an individual 35 mm. in length.

Fig. B6, from an individual 36 mm. in length.

Fig. B7, from an individual 50 mm. in length.

Fig. B8, from an individual 60 mm. in length.

Fig. C1 — Hand (natural size) from *C. whitmani*.

Fig. C2 — First pair of abdominal appendages (1½) of second-form male *C. whitmani*.

Figs. D1 to D3 inclusive show chela, rostrum and first pair of abdominal appendages of first-form males of the species *C. immunis*.

Fig. D1 — *c*, left chela, showing characteristic notch (*n*) near the base of the movable finger; *r*, typical *C. immunis* rostrum; *a*, first pair of abdominal appendages.

Fig. D2 — *c*, right chela without characteristic notch near base of movable finger; *r*, rostrum, not noticeably different from the rostrum shown in Fig. D1; *a*, first pair of abdominal appendages.

Fig. D3 — *c*, right chelæ, showing characteristic notch (*n*) near base of movable finger; *c*, left chela, without notch near base of movable finger and smaller than the right chela; *r*, rostrum, distinctly angled at the base of acumen; *a*, first pair of abdominal appendages.

Fig. E1 — Hand from a first-form male 71 mm. in length.

Fig. E2 — Hand from a second-form male 71.5 mm. in length.

Fig. E3 — Hand from a female 80 mm. in length.

Plate IV.

The figures in Plate IV. show comparisons between the reproductive organs and first pair of abdominal appendages in first-form and second-form males of *C. virilis*. All the reproductive organs shown are drawn from crayfish which were examined in June.

Fig. A — Reproductive organs from a second-form male without chelæ. *t*, testes, the three lobes slender, without secondary lobules; *v*, vasa deferentia, long and convoluted.

Fig. A1 — First pair of abdominal appendages taken from the same individual as the reproductive organs shown in Fig. A. They are thick, have narrow bases and closely approximated tips.

Fig. B — First pair of abdominal appendages of a second-form male without chelæ. Appendages are shown from the ventral side. The bases are narrow and do not meet in the median line.

Fig. B1 — Reproductive organs taken from the same individual as the appendages shown in Fig. B. *t*, testes. The connection between the lobes is very short and the two anterior lobes are only imperfectly separated; *v*, the vasa deferentia are short and unconvoluted.

Fig. C — First pair of abdominal appendages of a second-form male with chelæ. The bases are broad and the tips widely gaping.

Fig. D — Reproductive organs of a large first-form male. *t*, testes. The lobes are large and full, and are distinctly separated, anterior lobes unsymmetrical; *v*, vasa deferentia, much convoluted.

Figs. E, F and G are all taken from the same individual, a large male with chelæ.

Fig. E represents a side view of the first pair of abdominal appendages after the first moult.

Fig. F represents a ventral view of the same appendages, drawn in natural position. Note the closely approximated bases.

Fig. G represents the same pair of appendages just after second moult, showing transformation from second-form into first-form.

Fig. H — Two views of a first abdominal appendage of a second-form male with chelæ.

Fig. I — Typical reproductive organs of a first-form male. Lobes of the testes (*t*) widely separated and lobulated.

Fig. K — Chela (natural size) from a second-form male after it had moulted three successive times into second-form. Almost the entire growth had taken place within a single month.

Plate V.

Fig. A — Life-size drawing of *C. ayersii.*

Fig. B — Life-size drawing of *C. whitmani.*

Plate VI.

A series of figures reproduced from photographs of crayfish belonging to the species *C. rusticus*. Figures are about two-thirds natural size. These photographs represent a graded series of the species, showing variations in shape of rostrum and chelæ, in breadth of areola and in relative lengths of cephalothorax and abdomen.

Fig. 1 — Male *C. rusticus* (according to Faxon *C. neglectus*).

Fig. 2 — Male *C. rusticus* (according to Faxon *C. neglectus*).

Fig. 3 — Male *C. rusticus*. Note that the differences between Fig. 3 and Figs. 1 and 2 are not so great as are often seen between individuals that are constantly classed as the same species; *e. g.*, in *C. virilis*.

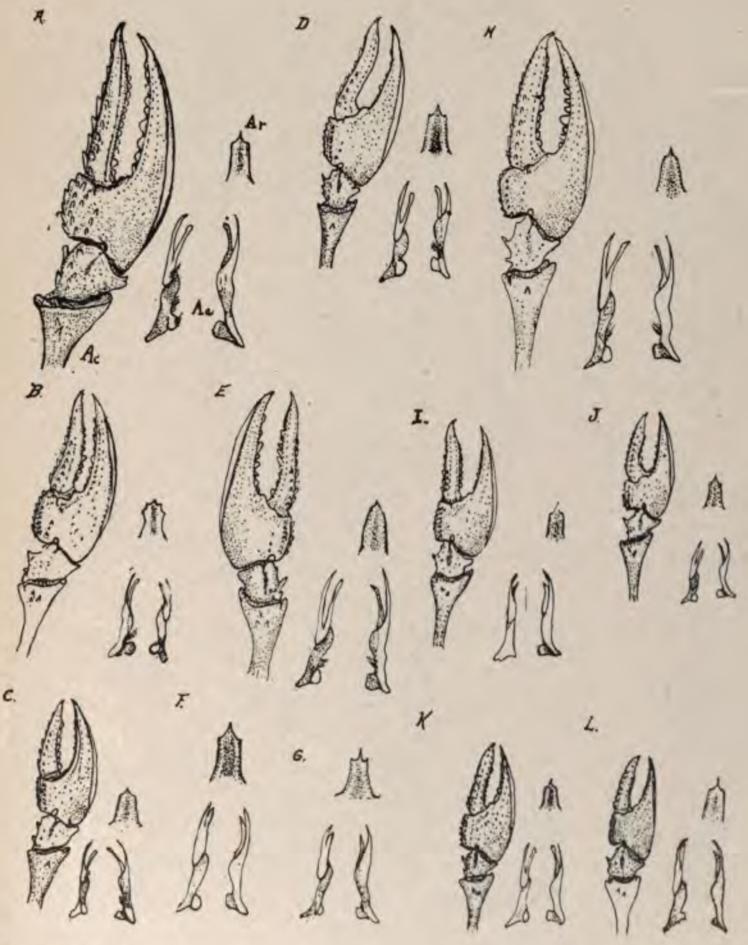
Fig. 4 — Female *C. rusticus*. Body contour closely resembles Figs. 1 and 2. Hands short and thick, as is usual in females of any species of Cambarus.

Fig. 5 — Male, *C. rusticus*. The chief difference between this figure and Figs. 1 and 2 lies in the rostrum, a feature which is found to be very inconstant in any species.

Fig. 6 — Male, *C. rusticus*. Rostrum from the rostra shown in Figs. 1 and 2, but not more different than from the rostra shown in Figs. 4 and 5.

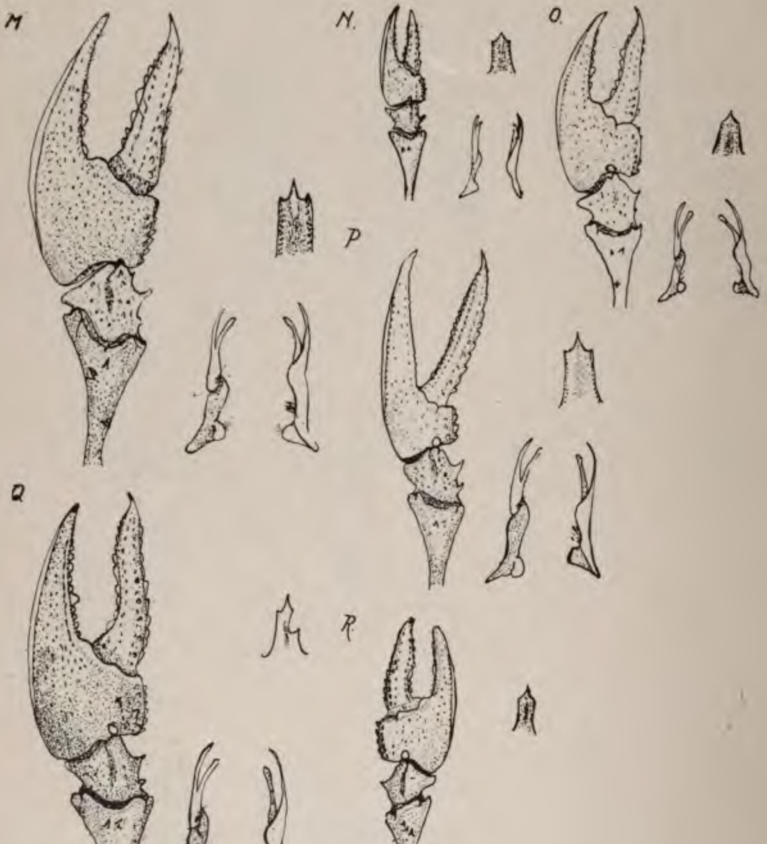
Fig. 7 — Male, *C. rusticus*. Rostrum and chelæ both different from the rostrum and chelæ shown in preceding figures.

Plate I.



M. Steele, del.

Crayfish of Missouri. Plate II.



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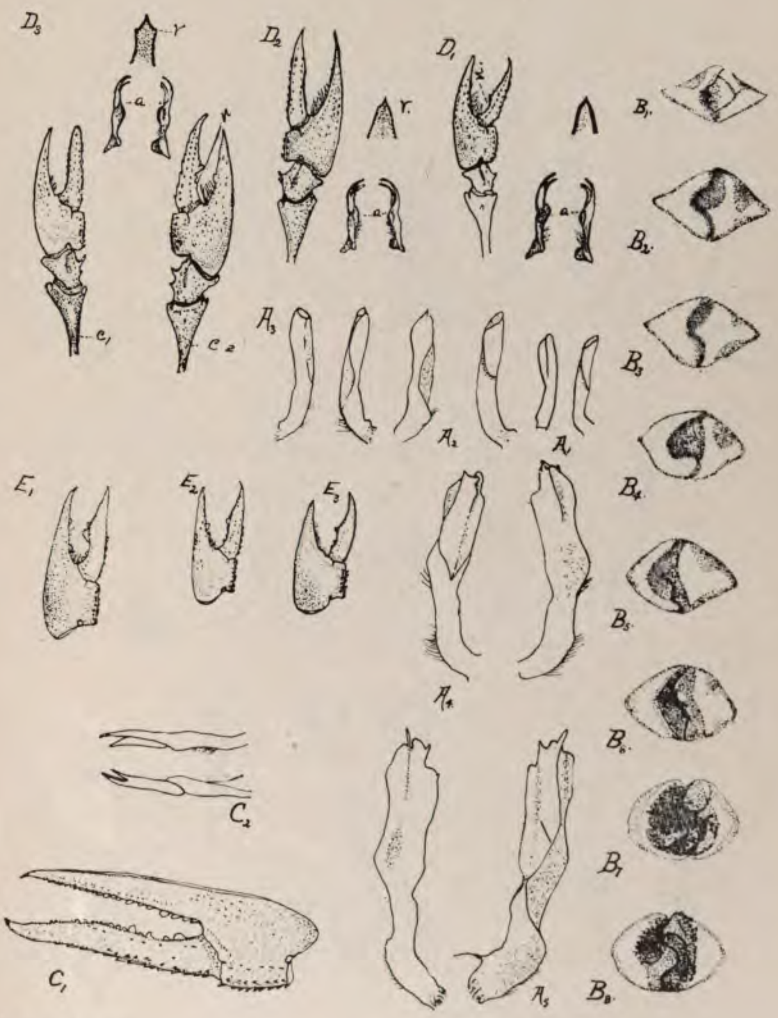
D3
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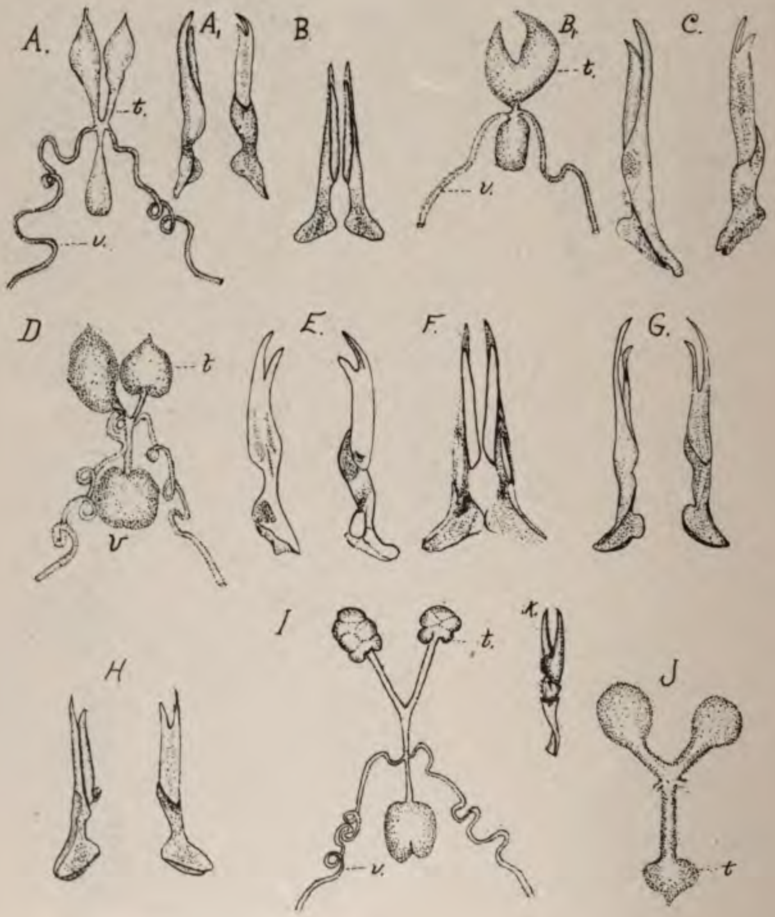
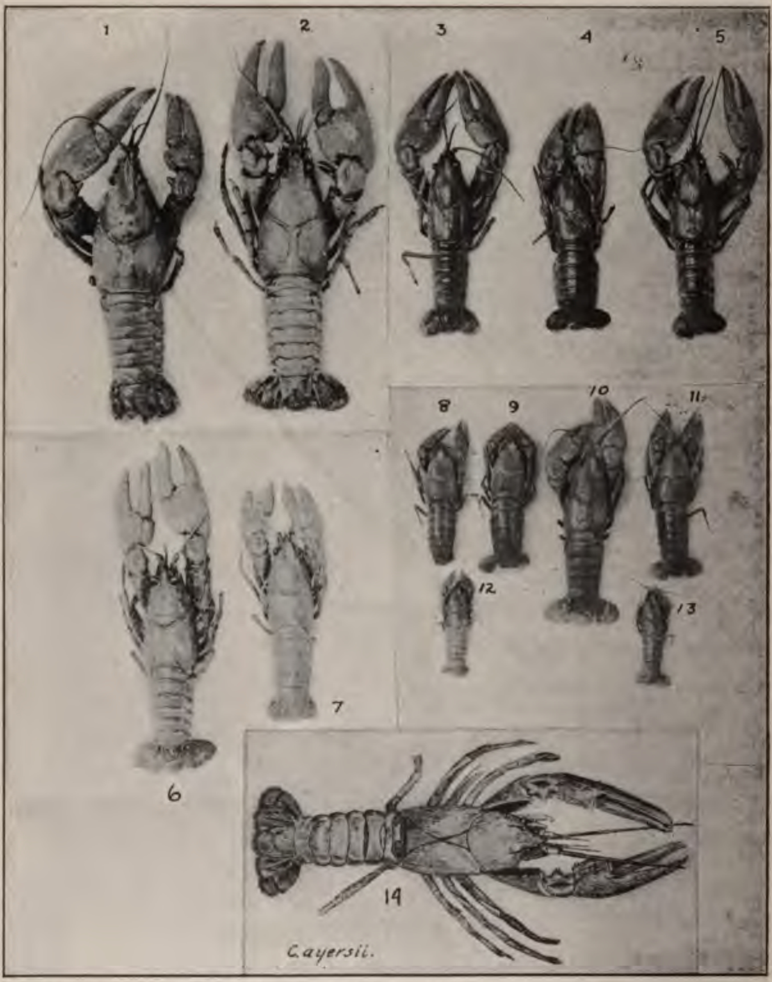
Plate IV.



M. Steele, del.

Note to the Reader: Plate V. is omitted but Fig. A is printed as Fig. 14 on Plate VI. Fig. B is not given.



M. Steele photo figs. 1-13. H. Ayers, del. fig. 14.